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DR. C. NEIL BERGLUND, PRINCIPAL INVESTIGATOR
PROFESSOR OF ELECTRICAL ENGINEERING & APPLIED PHYSICS
OREGON GRADUATE INSTITUTE OF SCIENCE & TECHNOLOGY
20000 NW WALKER ROAD
PO BOX 91000, PORTLAND, OR 97291-1000
TELEPHONE: (503) 690-1591
[redacted]
EMAIL: BERGLUND@EEAP.OGI.EDU

DR. YOON SOO PARK
PROGRAM OFFICER
CODE 312, ELECTRONICS DIVISION
OFFICE OF NAVAL RESEARCH
800 NORTH QUINCY STREET
ARLINGTON, VIRGINIA 22217-5660
703-696-5755

LOW TEMPERATURE MATERIALS GROWTH AND PROCESSING DEVELOPMENT FOR FLAT PANEL DISPLAY TECHNOLOGY APPLICATIONS

SPONSORED BY
OFFICE OF NAVAL RESEARCH
800 NORTH QUINCY STREET
ARLINGTON, VA 22217-5660

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
SEATTLE REGIONAL OFFICE
1107 NE 45TH STREET, SUITE 350
SEATTLE WA 98105-4631

IN REPLY REFER TO:

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Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

ROBERT J. SILVERMAN

FIELD EMITTER FLAT PANEL RESULTS

Anthony E Bell, Associate Professor

Graduate Assistants: Kit-sing Mak, Haibing Liu

I. SUMMARY

Objectives:

a) To understand the relative advantages and properties of diamond and graphite nanotubes as emission sources for FED displays.

b) To develop methods of growing uniform deposits of graphite (fullerene) nanotubes of nanometer scale diameters. It is believed that these field emitters will have the following properties:

1. Low turn-on voltages
2. Insensitivity to the vacuum ambient
3. Inexpensive methods of preparation
4. A compatibility with other industrial efforts - e.g. that of S.I. Diamond Corp.

c) To develop focused electron beam and focused ion beam (FIB) techniques for repairing flat panel display panels, especially those utilizing active matrix technology involving relatively small line widths.

II. TECHNICAL REPORT

Method of Approach:

a) Measure the work function, using a geometry independent absolute method, of diamond, both doped and undoped diamond, in order to establish the claims of ultra-low work function of n-doped diamond substrates.

b) Grow graphite nanotubes on Fe nuclei seeded on Si wafers and characterize them by inserting them in a vacuum viewing apparatus with a phosphor screen in order to ascertain the uniformity of electron emission over an area 1 cm x 1 cm. The wafer is heavily doped in order to be electrically conductive and is miscut by 5 degrees so that there will be a uniform density of step edge defects capable of accommodating and attracting the vacuum deposited Fe nanometer scale nuclei on which to anchor the growing carbon nanotubes.

c) Study different methods of depositing nanotubes, including plasma techniques.

d) Investigate methods of depositing metals and insulators using either electron and ion beams. Do this in collaboration with FEI Corporation, a local manufacturer of FIB and electron focused elctron beam systems.

Results:

a) Work in this quarter has been concentrated on developing models for the heating of the substrates occurring during the electron or ion beam heating of substrates. These modeling techniques were based on the ANSYS commercially available software finite-element package that is capable of handling 3-dimensional geometries. This work has been completed and shows that significant heating can occur for low thermal conductivity materials like SiO_2 for electron beam heating. Focused ion beams appear to be too low in intensity to effect substrate temperatures to any significant degree.

b Fowler Nordheim results have been obtained from nanotube graphite deposits but appear to indicate either that the nanotube emission does not follow the usual Fowler Nordheim relationship or that there is a Fowler Nordheim mechanism superimposed on a leakage current background.

c) Considerable effort has been made to characterize, using the TEM, nanotubes made by using different combinations of deposition techniques.

III. FUTURE EFFORT

Work for the next quarter:

a) Work will commence in using the FEI equipment to investigate advanced methods for depositing insulators and metals using focused electron beams.

b) Work will be devoted to the viewing of nanotube emission using a phosphor screen.

c) Efforts will be made in collaboration with Bill Mackie of Linfield College, McMinnville, Oregon to obtain samples of SI Diamond “amorphic” carbon films for work function measurements.

Modeling of a-Si TFTs for Liquid Crystal Display Applications

V. S. Rao Gudimetla

Department of Electrical Engineering and Applied Physics
Oregon Graduate Institute

Background:

The project goal is to make DC, AC, transient measurements on the TFTs, fabricated by Professor Sigmon and his group at Lawrence Livermore National Laboratory using low temperature processing techniques. From these measurements, SPICE parameters will be extracted and these results will be used for process monitoring and device and process optimization for display applications. This work was started by Rao Gudimetla on 10/1/94 and this technical report is for the period 8/14/95 to 11/14/95.

Work Schedule and Results:

During the above project period, Rao Gudimetla spent major part of his time at Lawrence Livermore National Laboratory (LLNL) as a Participating Guest and worked closely with Dr. Sigmon's group.

We have started analyzing the I-V data from several TFTs fabricated at LLNL over the last six months at various times and compared the experimental data with PISCES simulations. Some of the devices have poor drain to source current (Ids) and high threshold voltages. Spice modeling was not yet been pursued aggressively as these problems must be resolved first and several reliable a-Si TFTs must be fabricated.

Extensive simulation studies that involve a critical examination of the effects of sheet resistance under the contacts, contact resistances, overlap/underlap of the gate metallization with those of source and drain contacts, deep-level defects, tail states and a-Si layer thickness (marginal fine tuning) on Ids and threshold voltage were completed.

After reviewing these studies, it was concluded that either contact underlap (no overlap between gate contact with source and drain contacts) or enhanced deep level defects are responsible for the poor performance of the devices. In particular, it was noticed that effect of the deep-level states is dramatic with respect to increase in the threshold voltage and the underlap of the contacts leads to a drastic decrease in Ids. A further examination of the relative roles of deep and tail states was also completed.

Immediate Future Goals:

1. New devices with good contact overlap will be fabricated first and the devices will be checked for good performance.

2. If the new devices perform well, possibility of hydrogenation will be explored to reduce the threshold voltage.

3. We have done some more work on the theories involving the electrical properties of the grain boundary for use in developing a reliable SPICE model for TFTs but could not complete it due to a concentrated effort on the above simulation studies.

<u>Quarterly Progress Report.</u>

Electroluminescent Displays Research Group.
PIs: R. Engelmann, R. Solanki
Graduate Student: J. Ferguson

The objective of our investigation is to demonstrate the proof of concept of quantum well electroluminescent (EL) phosphors. Unlike traditional EL phosphors where activators (dopants) are the source of light, our goal is to produce light from artificially engineered materials, namely multiple quantum wells(MQW).

The material system we have selected to demonstrate the activatorless emission consists of CdSe quantum wells in a SrS host. The reason for choosing this combination was a close lattice match of cubic phases of these compounds and higher probability of achieving quantum confinement of carriers due to relatively large mismatch of the conduction and valence bands. This has been discussed in our previous reports.

We initially optimized growth of SrS from $Sr(thd)_3$ and H_2S using atomic layer epitaxy (ALE), as reported previously. CdSe films were grown using Cd and Se elemental precursors. One of the problems we encountered using elemental Cd and Se precursors was that, in the deposition temperature range of 300 to 400° C, the phase of the film became predominantly hexagonal. Considerable effort was expended by varying all the deposition parameters to achieve cubic phase growth; however, this proved to be futile. Therefore, we decided to proceed with the quantum well growth with hopes of achieving pseudomorphic growth with thin CdSe layers.

A set ofMQW EL devices were fabricated with the conventional structure, where the phosphor film is sandwiched between two insulator layers(~ 2300 Å). All the devices had 10 CdSe QWs separated by 400 Å thick SrS layers. The CdSe QW thickness ranged from 150 Å to 30 Å thick. These devices were tested with bipolar voltage pulses.

Optical emission was obtained from all the MQW devices with remarkably low threshold fields. Brightness, though, still needs to be enhanced. The emission from the thicker QW (100-150 Å) devices had a reddish appearance whereas that of the thinner (30-50 Å) QW samples had a bluish appearance. The emission spectra from 150 Å and 100 Å MQWs devices is shown in Fig. 1. This can be compared with the emission from a 30 Å MQW device shown in Fig.

2. One can note the blue shift of the emission as the QW width is reduced. At this time we are in the process of analyzing our data and explaining the origin of the various peaks of the emission spectra. These results will be discussed in the next quarterly report.

We can summarize our results to date as follows:

1. EL emission from a MQW phosphor, which was the goal of our investigation, has been demonstrated for the first time. Thus the basic concept of MWQ EL phosphors has been proven but extensive further studies are required to understand the complexity of the emission spectra and to improve emission strength.

2. The MQW structures were achieved in a poly-crystalline material using ALE.

3. The emission threshold was 60V, which is significantly lower than that of conventional EL devices (120-140 V) of similar thickness.

4. A blue shift of emission wavelegth for smaller QW size was observed, consistent with the QW effect.

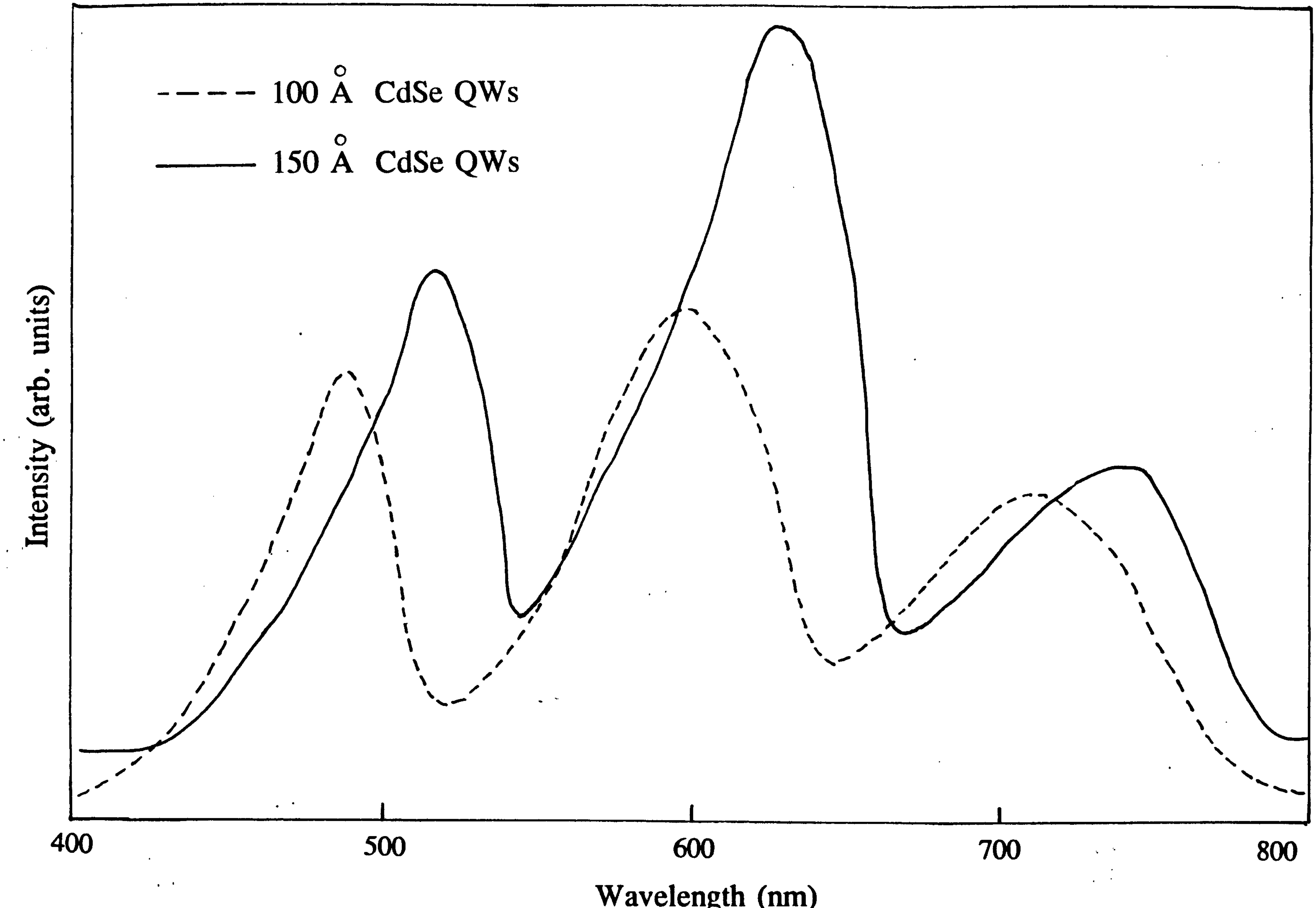
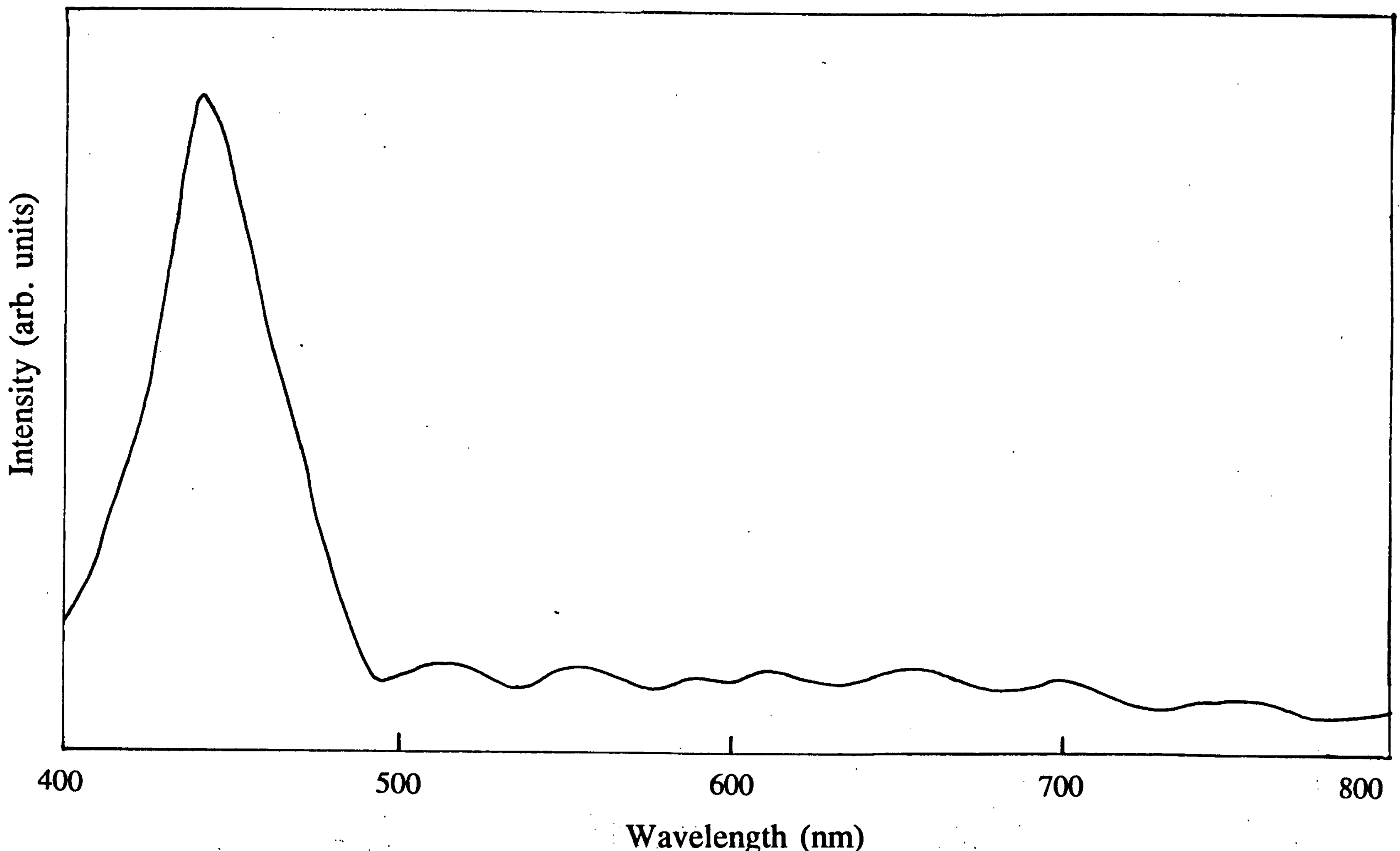


Fig. 1. Emission spectra of 150 Å and 100 Å thick QW EL devices.

Fig. 2. Emission from 30 Å thick CdSe QW EL device.



EVALUATION OF PULSED UV-LASER GAS PHASE DOPING FOR FABRICATION OF HIGH PERFORMANCE POLYSILICON TFTs

Thomas Sigmon, Professor

I. SUMMARY

The primary purpose of this research effort is to investigate and characterize the use of Gas Immersion Laser Doping (GILD) for the fabrication of polysilicon thin-film transistors (TFTs). Last quarter's report described the development of a new GILD TFT mask set specifically optimized for fabricating both conventional and laser processed TFTs. Section II of this quarter's report shows initial results obtained through the use of this new mask set, as applied to the optimization of the laser recrystallization process for the TFT active area. Future efforts are summarized in Section III.

II. TECHNICAL REPORT

Our research is directed toward improving an TFT's performance through laser processing. There are two major laser processing steps under investigation, being laser recrystallization of the TFT active area (i.e. channel region), and GILD source and drain doping. The former research thrust has received much attention by the research community, whereas the latter thrust has received little, if any, serious attention. In any self-aligned TFT process sequence, the source and drain doping occurs after the channel has been defined by the gate. So it makes sense to study/optimize the laser recrystallization of the channel region before investigating the GILD source and drain doping process. This report presents initial results of an effort to optimize the laser processing parameters for active are recrystallization.

The experiment is briefly summarized as follows. Several 4" Si (100) wafers were thermally oxidized to 3000 A, on which 900 A of a-Si was deposited by LPVCD. A subsequent two day 600 C furnace anneal transformed the a-Si into poly-Si. The poly-Si film was then irradiated with an XeCl excimer laser (308 nm) at ten different energies, ranging from surface heating to ablation, with 1 and 10 laser pulses at each energy. Laser processing occurred at room temperature in 100 Torr of nitrogen. Some of the poly-Si films were irradiated in an BF3 ambient (100 Torr) to dope the film with boron. Later SIMS analysis used the boron tail as a melt depth marker.

The criteria for judging the quality of the laser recrystallized poly-Si films was mainly grain size, and the absence of in-grain defects (i.e. microtwins, dislocations, point defects, etc.). Many analytical techniques exist to evaluate these qualities. As part of our research, we had to develop an efficient analytical feedback scheme for analyzing the laser processed film quality. We chose TEM as our main technique for analyzing the poly-Si films because it shows exactly what the grains look like, and unlike Raman spectroscopy, X-Ray diffraction, and UV reflectance methods, there is little ambiguity in interpreting the data. Complementing the TEM analysis, an atomic force microscope was used to evaluate surface roughness, and SIMS was used on GILD doped samples to monitor the melt depth.

An analysis of the laser recrystallized poly-Si films shows that irradiation at an energy below the energy needed to fully melt the poly-Si film preserves the grain size of the original solid-phase crystallized poly-Si film. However, as the laser energy increases (in this range) there are less in-grain defects, and the surface becomes rougher. As the literature reveals, the molten poly-Si solidifies using the poly-Si below it as a seed for regrowth. Therefore, the grain size does not change, but the defects within each grain can be annealed out. Since solid-phase

crystallized poly-Si films typically have much larger grains than laser recrystallized a-Si films large grains with little in-grain defects can be produced by combining the two different types of anneals.

As the laser energy is increased past the threshold energy needed to melt the poly-Si film completely, or past the "full melt threshold energy," the grain size is drastically reduced to a few hundred Angstroms. An SIMS analysis of boron GILD doped samples was used to verify that the grain size shrinks past the full melt threshold energy. In this energy range, the laser process behaves similarly to that seen using a-Si as a starting material for recrystallization. The literature speculates that when the laser energy exceeds the full melt threshold energy, the laser introduces defects at the molten Si/oxide interface, and these defects become nucleation sites for grain growth upon solidification.

The same grains resulted from 1 and 10 laser pulses. It remains to be seen if an energy exits that produces secondary-grain growth, or super-lateral grain growth as it is sometimes called in the literature, in these poly-Si films. Such grain growth has been seen in laser crystallized a-Si films when irradiated at the full-melt threshold energy. Much larger grains are created at such an energy. At the present time, only two papers exist on laser crystallization of previously solid-phase crystallized films, and these papers work at laser energies much below the full melt threshold energy. Our research on these films is therefore relevant.

In summary, the best poly-Si laser annealed films occurred just before the full melt threshold energy, as the resulting poly-Si grains retain their original solid-phase crystallized (large) grain sizes, and have little in-grain defects after laser processing. The number of laser shots does not seem to effect the grain quality. Since we did not irradiate these films at the full melt threshold energy we cannot say whether or not they exhibit secondary grain growth.

III. FUTURE EFFORT

This quarter completed the initial experiments to optimize the laser recrystallization of TFT active areas. We understand the evolution of grain quality with different laser processing conditions, and have started to narrow in on what laser conditions would be the best to operate with. Goals for future quarters include the following:

i) Repeat this experiment at the full melt threshold energy to see if much larger grains result from secondary grain growth.

ii) Work on optimizing GILD processing conditions for low-resistivity laser-doped poly-Si.

iii) Having completed goals i) and ii), proceed with TFT Run 2